APPENDIX F
Newmark Wellfield Extraction System Technical Memorandum

NEWMARK WELLFIELD
EXTRACTION SYSTEM
TECHNICAL MEMORANDUM

NEWMARK OPERABLE UNIT
REMEDIAL DESIGN

Prepared for:

Contract No. 68-W9-0054 / WA No. 54-37-9NJ5
U.S. Environmental Protection Agency
Region IX
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March 1995

NEWMARK WELLFIELD EXTRACTION SYSTEM TECHNICAL MEMORANDUM
NEWMARK OU RD
URS Consultants, Inc.
ARCS, EPA Region IX
Contract No. 68-W9-0054 / WA No. 54-37-9NJ5

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1   **NEWMARK WELLFIELD EXTRACTION SYSTEM**
2   **TECHNICAL MEMORANDUM**

3   **1.0   INTRODUCTION**

4   This memorandum describes the extraction well locations for the Newmark wellfield extraction system
5   for the Newmark Operable Unit (OU). Presently, the City of San Bernardino extracts groundwater from
6   four existing wells in the Newmark wellfield, identified as Newmark wells 1, 2, 3, and 4. The extraction
7   system proposed in this memorandum includes the existing Newmark wells 1 and 3, as well as two new
8   extraction wells. Design of the system includes the location, number, and extraction rates of the proposed
9   new extraction wells. The physical design of the extraction wells (e.g., casing diameter, screen interval
10   and size, packing materials) will be completed when the pilot borings for the extraction wells are drilled.
11   The project flow model was used to determine extraction well locations and flow rates. Computer runs
12   performed during the feasibility study phase were used as the starting point for the design presented
13   herein. System extraction rates were refined using analytical capture zone calculations adapted from
14   Javandel and Tsang (1986).

15   During the feasibility study, the Newmark OU remedial investigation/feasibility study (RI/FS) report
16   (URS 1993a) identified two extraction well systems for control of the Newmark OU groundwater plume:
17   (1) one extraction well system included the Newmark wellfield (located just north of Shandin Hills); and
18   (2) a new extraction well system located near the maximum contaminant level (MCL) isoconcentration
19   for tetrachloroethene (PCE) along Baseline Street in the City of San Bernardino. Two existing
20   groundwater facilities, termed here as the north treatment plant and the south treatment plant, were
21   identified in the Newmark OU RI/FS report. The extracted groundwater from the Newmark wellfield
22   and the new extraction systems were to be conveyed to the north and south treatment plants, respectively.
23   Further details of the extraction systems were described in the Newmark OU RI/FS report (URS 1993a).

24   **1.1   SCOPE AND OBJECTIVE**

25   The goal of the Newmark wellfield extraction system is to minimize further migration of the northern
26   portion of the Newmark groundwater contaminant plume. The proposed extraction well system is located
27   just north of Shandin Hills. The objectives of this memorandum are to determine the following:

28   (1)   Location of the Newmark wellfield extraction wells;
29   (2)   Number of extraction wells; and
30   (3)   Pumping rate estimates for the extraction wells.

31   **1.2   BACKGROUND**

32   Initially, groundwater modeling was performed for what later was termed the Newmark OU. This effort
33   involved: (a) development of the project flow model for the *Newmark Groundwater Contamination*
34   *Superfund Site,* and (b) application of the project flow model to evaluate extraction scenarios for the
35   Newmark OU. The following reports resulted from that modeling effort:

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1   ■   Newmark Project Flow Model Technical Memorandum, Part I (URS 1991)
2   ■   Newmark Project Flow Model Technical Memorandum, Part II (URS 1992)
3   ■   Newmark OU RI/FS Report, Appendix J - Newmark Project Flow Model Technical
4   Memorandum (URS 1993a)
5   ■   Newmark OU RI/FS Report, Appendix M - Development of Extraction Scenarios (URS
6   1993a)

7   The project flow model was further refined in the vicinity of the Muscoy Plume west and south of
8   Shandin Hills. The refined model was used to evaluate extraction and injection scenarios for the Muscoy
9   Plume OU RI/FS. The following reports resulted from that modeling effort:

10   ■   Muscoy Groundwater Modeling Memorandum (URS 1993b)
11   ■   Muscoy Plume OU RI/FS Report, Appendix 6 - Development of Extraction Scenarios (URS
12   1994a)

13   The project flow model was used to assist in designing a new extraction well system near the MCL
14   isoconcentration for PCE along Baseline Street. The following technical memorandum resulted from the
15   design effort:

16   ■   Newmark Plume Front Extraction Well Technical Memorandum (URS 1995)

17   The model was also used to help design the Newmark wellfield extraction system. The remaining
18   portions of this memorandum are divided into three sections: (1) extraction well system design; (2)
19   conclusions; and (3) references.

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1   ## 2.0   EXTRACTION WELL SYSTEM DESIGN

2   This section describes five extraction well scenarios that were simulated using the project flow model and
3   is divided into six subsections: (1) a brief description of the Newmark groundwater plume; (2) a
4   description of model extraction scenarios considered in this memorandum; (3) the results of the extraction
5   scenario model runs; (4) a description of model limitations; (5) an evaluation of recent pumping test
6   results and capture zone calculations; and (6) presentation of proposed extraction well locations and
7   extraction rates.

8   ### 2.1   NEWMARK GROUNDWATER PLUME

9   Figure 1 shows measured PCE concentrations in groundwater monitoring and municipal supply wells in
10   the vicinity of the Newmark wellfield. The PCE concentrations are based on groundwater quality data
11   obtained from the municipal supply and monitoring wells during April 1993 and November 1994 (MW09
12   only). The data obtained in April 1993 are presented in the Interim Sampling Report (URS 1993c). A
13   report presenting November 1994 data will be submitted to the EPA in the near future. Although the
14   number of wells available to delineate the extent of the plume was limited, a conservative approach was
15   used to interpret the data. The data suggest that only the lower portion of the saturated zone is
16   contaminated with PCE and trichloroethene (TCE).

17   ### 2.2   EXTRACTION SCENARIOS

18   A total of five extraction scenarios were simulated during the modeling effort. Since the objective was
19   to select an extraction system with the optimum number, pumping rate, and well locations, a combination
20   of these three factors was used to devise the five scenarios. Only Newmark production wells 1, 3, and
21   4, along with two new wells, were used in the extraction scenarios. The new extraction wells were
22   placed south of the Newmark wells and north of Shandin Hills (Figure 1). The locations align north to
23   south, which is considered effective in cutting off the eastward movement of contaminants in the
24   Newmark wellfield area. The simulated extraction wells were screened only in the upper portion of the
25   aquifer (or layer one of the model) because the Newmark wellfield area consisted of one aquifer as
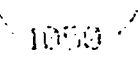26   opposed to the areas south of Shandin Hills where two aquifers (and two model layers) were identified.
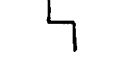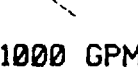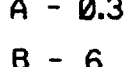
27   ### 2.3   RESULTS OF THE EXTRACTION SCENARIOS

28   Each extraction scenario was executed as follows:

29   ■   MODFLOW was run for each extraction scenario to simulate flow conditions for 35 years
30   (or 140 stress periods) starting from January 1986 to December 2020.

31   ■   The results from the MODFLOW runs were used as input for PATH3D© to create imaginary
32   particle pathlines.

33   ■   The output files from PATH3D© were used in SURFER® to produce plots of head contours,
34   pathlines of imaginary particles, and locations of extraction areas.
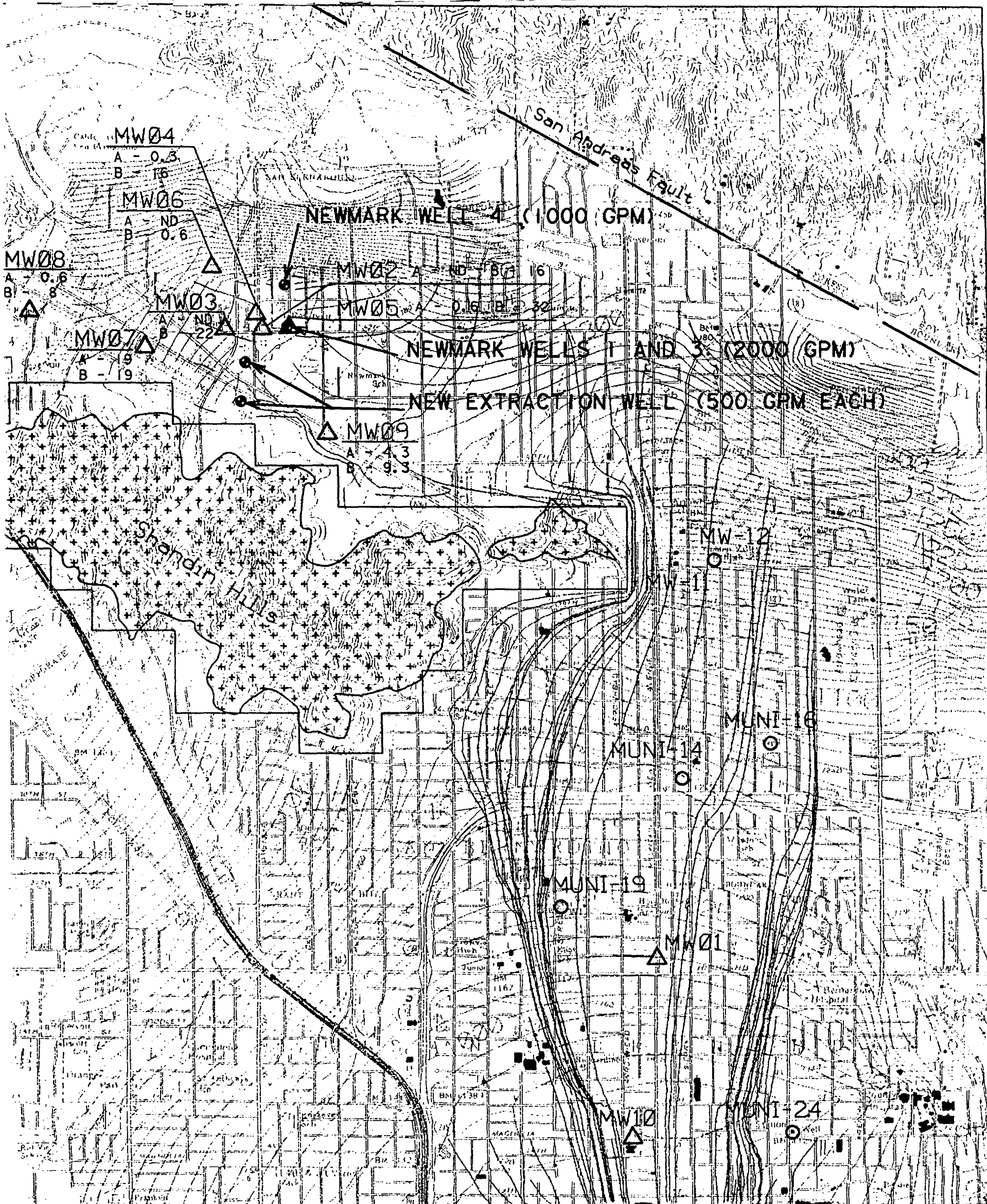
LEGEND

$\sim 1000 \sim$	Line of Equal Head (Interval = 5ft)
⬡	Bedrock Outcrop
⌐	Boundary of No Flow Area
╲	Imaginary Particle Pathline
1000 GPM	Extraction Rate
△	Monitoring Wells
⊙	Municipal Supply Wells
A - 0.3	PCE Concentration (ug/l) in Subunit A
B - 6	PCE Concentration (ug/l) in Subunit B

Note : Concentrations of PCE in Groundwater are Based on April 1993 and November 1994 Sampling Data.

Only PCE Data In The Wells Near The Newmark Wellfield are Shown

ND - Non-Detect

0'   2000'   4000'

SCALE IN FEET

FIGURE 1

MODFLOW RUN 63A
PATHLINE PLOT AND
EXTRACTION WELL LOCATIONS

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NEWMARK GROUNDWATER CONTAMINATION SUPERFUND SITE

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1　　To create pathlines of imaginary particles, two sets of imaginary particles (a total of 89) were used in
2　　PATH3D©. Set no. 1 contained sixty-eight imaginary particles that were placed approximately along the
3　　boundary of the upgradient plume. Set no. 2 contained twenty-one imaginary particles that were placed
4　　in the vicinity of the plume front and represented a zone of contamination believed to be equivalent to
5　　the MCL for PCE (5 $\mu g/\ell$). Locations of the imaginary particles are listed in Table 1.

6　　The pathline of an imaginary particle produced by PATH3D© represents predicted movement of
7　　groundwater in the aquifer over time. Because the contaminants (TCE and PCE) move with the
8　　groundwater, the imaginary particle pathline also represents the predicted movement of contaminants in
9　　the aquifer over time. The pathlines of the 89 imaginary particles, therefore, represent the predicted
10　　movement of contaminants in the Newmark OU. The extraction scenarios were evaluated based on
11　　predicted capture of imaginary particles by the extraction wells. Pumping details and results of the
12　　extraction scenarios are presented below.

13　　Table 2 summarizes the details of the five simulated extraction scenarios. Table 3 lists the extraction
14　　scenario parameters. All the extraction scenarios were simulated for a duration of 35 years, starting from
15　　January 1986 and continuing through December 2020.

16　　Extraction scenario no. 1 (run 63A) was similar to extraction scenario no. 6 in the Newmark OU RI/FS
17　　report (URS 1993a). The extraction system in scenario no. 1 consisted of Newmark wells 1, 3, and 4
18　　and two new wells. A constant pumping rate, which remained the same over the simulation period, was
19　　used. The total pumping from the wells was 4,000 gpm. Figure 1 shows the groundwater elevation
20　　contours and imaginary particle pathlines for run 63A. The results presented in this figure showed that
21　　all the imaginary particles introduced upstream, and a number of imaginary particles that were placed
22　　downstream, were captured. However, the grid cells where Newmark wells 1, 3, and 4 were located
23　　went dry during the simulation.

24　　Extraction scenario no. 2 (run 63B) used Newmark wells 1, 3, and 4. The wells were pumping at a
25　　constant rate with a total of 3,000 gpm. The results showed that all the imaginary particles introduced
26　　upstream, and a number of imaginary particles placed downstream, were captured. One grid cell located
27　　near a no-flow boundary of Shandin Hills went dry during the run. Because the dry grid cell was at a
28　　distance and downgradient from the wells, it did not significantly affect the simulation.

29　　Extraction scenario no. 3 (run 63C) used Newmark wells 1, 3, and 4 and two new wells with a constant
30　　pumping rate that produced a total of 2,700 gpm. No dry cells were observed in this run. The scenario
31　　was effective in capturing the particles.

32　　Extraction scenarios no. 4 (run 63D) and no. 5 (run 63E) used Newmark wells 1, 3, and 4 and one new
33　　well. The scenarios were effective in capturing the imaginary particles. Two grid cells located at a
34　　distance from the wells, downgradient, and near the no-flow boundary of Shandin Hills, went dry during
35　　the simulation.

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Table 1

IMAGINARY PARTICLE LOCATIONS FOR EXTRACTION SCENARIOS

Particle(s)	Model Cell (j,i,k)	Particle(s)	Model Cell (j,i,k)
		Set 1	
1	(31,26,1)	35	(35,24,1)
2	(36,26,1)	36	(35,23,1)
3	(36,27,1)	37	(35,22,1)
4	(36,28,1)	38	(34,21,1)
5	(36,29,1)	39	(33,20,1)
6	(36,30,1)	40	(32,19,1)
7	(36,30,2)	41	(31,19,1)
8	(35,31,1)	42	(30,18,1)
9	(35,31,2)	43	(29,18,1)
10	(35,32,1)	44	(28,17,1)
11	(35,32,2)	45	(27,17,1)
12	(35,33,2)	46	(26,17,1)
13	(35,34,2)	47	(25,17,1)
14	(35,35,2)	48	(24,17,1)
15	(35,36,2)	49	(23,17,1)
16	(34,37,2)	50	(22,17,1)
17	(33,38,2)	51	(21,17,1)
18	(32,38,2)	52	(21,18,1)
19	(31,38,2)	53	(21,19,1)
20	(30,37,2)	54	(21,20,1)
21	(30,36,2)	55	(22,20,1)
22	(29,35,2)	56	(23,20,1)
23	(29,34,2)	57	(24,21,1)
24	(29,33,2)	58	(25,22,1)
25	(29,32,1)	59	(26,22,1)
26	(29,32,2)	60	(27,22,1)
27	(29,31,1)	61	(28,22,1)
28	(29,31,2)	62	(29,22,1)

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Table 1 (Cont'd.)

IMAGINARY PARTICLE LOCATIONS FOR EXTRACTION SCENARIOS

Particle(s)	Model Cell (j,i,k)	Particle(s)	Model Cell (j,i,k)
29	(29,30,1)	63	(30,22,1)
30	(29,30,2)	64	(31,22,1)
31	(29,29,1)	65	(32,22,1)
32	(30,28,1)	66	(32,23,1)
33	(30,27,1)	67	(32,24,1)
34	(36,25,1)	68	(31,25,1)
Set 2			
69	(28,38,2)	80	(32,41,2)
70	(29,38,2)	81	(33,41,2)
71	(30,38,2)	82	(34,41,2)
72	(31,38,2)	83	(29,40,2)
73	(32,38,2)	84	(30,40,2)
74	(33,38,2)	85	(31,40,2)
75	(34,38,2)	86	(32,40,2)
76	(35,38,2)	87	(33,40,2)
77	(29,41,2)	88	(34,40,2)
78	(30,41,2)	89	(35,40,2)
79	(31,41,2)		

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Table 2

SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
63A	1) Evaluate extraction well placement and extraction volume to establish plume capture.	1) Scenario no. 6 in Newmark RI/FS used 4 existing Newmark wells (1, 2, 3, and 4) and 1 new extraction well for the Newmark wellfield extraction system. The extraction rate in the 4 Newmark wells was cyclical (i.e., pumping rate changed from quarter to quarter) and the first 5-year pumping cycle of 01/86 through 12/90 was repeated for every five years to simulate 35 years. Run 63A used 3 existing Newmark wells (1, 3, and 4) and 2 new extraction wells (Newmark well 2 was assumed to be shut off). 2) Input files from run 62H were modified to include: - Newmark wells 1 and 3 pumping a total of 2,000 gpm from 01/91 onward. - Newmark well 4 pumping @ 1,000 gpm from 01/91 onward. - 2 new extraction wells each pumping @ 500 gpm.	1) Simulation converged with 0.01% water balance discrepancy. 2) The Newmark wellfield extraction system captured all imaginary particles introduced upgradient and a number of imaginary particles introduced downgradient. The grid cells where Newmark wells 1, 3, and 4 were located went dry.
63B	1) Evaluate extraction well placement and extraction volume to establish plume capture.	1) Runs 63B and 63A were identical except that in run 63B, the two new extraction wells were not used. 2) Input files from run 63A were modified to include: - Newmark wells 1 and 3 pumping a total of 2,000 gpm from 01/91 onward. - Newmark well 4 pumping @ 1,000 gpm from 01/91 onward.	1) Simulation converged with 0.01% water balance discrepancy. 2) The extraction system captured all upgradient imaginary particles and a number of imaginary particles introduced downgradient. One grid cell located far away, downgradient, and near no-flow boundary of Shandin Hills went dry.

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SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
63C	1) Evaluate extraction well placement and extraction volume to establish plume capture.	1) Location of extraction wells in run 63C was the same as in run 63A, but pumping from Newmark wells was reduced. 2) Input files from run 63B were modified to include: - Newmark wells 1 and 3 pumping a total of 900 gpm from 01/91 onward. - Newmark well 4 pumping @ 800 gpm from 01/91 onward. - 2 new extraction wells each pumping @ 500 gpm.	1) Simulation converged with 0.01% water balance discrepancy. 2) The extraction system captured all imaginary particles introduced upgradient and a number of imaginary particles introduced downgradient. None of the cells near the extraction system went dry.
63D	1) Evaluate extraction well placement and extraction volume to establish plume capture.	1) Location of extraction wells in run 63D was the same as in run 63C, but pumping in Newmark wellfield was changed and only one new extraction well was used. 2) Input files from run 63C were modified to include: - Newmark wells 1 and 3 pumping a total of 1,500 gpm from 01/91 onward. - Newmark well 4 pumping @ 800 gpm from 01/91 onward. - Only one new extraction well pumping @ 500 gpm.	1) Simulation converged with 0.01% water balance discrepancy. 2) The extraction system captured all upgradient imaginary particles and a number of imaginary particles introduced downgradient. Two grid cells located far away, downgradient, and near no-flow boundary of Shandin Hills went dry.

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SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
63E	1) Evaluate extraction well placement and extraction volume to establish plume capture.	1) Location and pumping from extraction wells in run 63E was the same as in run 63A, except in run 63E only one new extraction well was pumping. 2) Input files from run 63A were modified to include: - Newmark wells 1 and 3 pumping a total of 2,000 gpm from 01/91 onward. - Newmark well 4 pumping @ 1,000 gpm from 01/91 onward. - Only one new extraction well pumping @ 500 gpm.	1) Simulation converged with 0.01% water balance discrepancy. 2) The extraction system captured all upgradient imaginary particles and a number of imaginary particles introduced downgradient. Two grid cells located far away, downgradient, and near no-flow boundary of Shandin Hills went dry.

Notes:
- All the runs were simulated for a period of 35 years from January 1986 through December 2020.
- New extraction wells were assumed to begin pumping from 6th year of simulation (i.e., pumping in extraction wells simulated for 30-year period January 1991 through December 2020).
- Newmark wells 1, 2, 3, and 4 were at normal pumping rates from January 1986 through December 1990.
- Newmark well 2 was considered turned-off in the runs from January 1991 onward.
- Pumping rates were changed for Newmark wells 1, 3, and 4 from January 1991, as shown in the table for different simulations.
- The extraction runs included normal (or actual) pumping from 19th St. No. 1 and No. 2 wells for first 5-year period between January 1986 through December 1990.
- The extraction runs included pumping from 19th Street No. 1 and No. 2 each at 1,500 gpm from 01/91 onward; and pumping from the Baseline Feeder wellfield from January 1991 onward.
- The Baseline Feeder wellfield includes Perris St. and 9th St. City of San Bernardino wells.

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Table 3

EXTRACTION SCENARIOS
FOR NEWMARK WELLFIELD REMEDIAL DESIGN

Model Run	Extraction Scenario	Newmark Wellfield Extraction Well System	Pumping Rate (gpm)	Number of Extraction Wells	Total Pumping (gpm)
63A	No. 1	Newmark Wells 1 & 3 Newmark Well 4 New Extraction Well 1 New Extraction Well 2	2,000 1,000 500 500	5	4,000
63B	No. 2	Newmark Wells 1 & 3 Newmark Well 4 New Extraction Well 1 New Extraction Well 2	2,000 1,000 0 0	3	3,000
63C	No. 3	Newmark Wells 1 & 3 Newmark Well 4 New Extraction Well 1 New Extraction Well 2	900 800 500 500	5	2,700
63D	No. 4	Newmark Wells 1 & 3 Newmark Well 4 New Extraction Well 1 New Extraction Well 2	1,500 800 500 0	4	2,800
63E	No. 5	Newmark Wells 1 & 3 Newmark Well 4 New Extraction Well 1 New Extraction Well 2	2,000 1,000 500 0	4	3,500

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2.4   LIMITATION OF MODEL RUNS

Models typically contain limitations resulting from uncertainty associated with model input parameters. Several limitations inherent with the project flow model lead to uncertain groundwater capture in the vicinity of the Newmark wellfield. A list of significant model limitations in the vicinity of the Newmark wellfield follow:

- Juxtaposition of complex boundary conditions (particularly the no-flow boundaries along the Shandin Hills and San Andreas fault);

- Significant influx of groundwater from the west (through the Shandin Hills -- Wiggins Hill gap) which cannot be simulated with the model as presently calibrated;

- Large seasonal variations in groundwater levels not simulated in the model; and

- Additional groundwater level fluctuations as a result of State Project Water being spread upgradient of the Newmark wellfield. These water imports are not predictable and were not simulated.

The first two bullets probably contributed to model cells dewatering during the extraction simulations.

As indicated in Table 2, grid cells went dry when large pumping rates were simulated at the Newmark wellfield. The maximum total pumping rate that produced no dry cells was 2,700 gpm (extraction scenario no. 3). Aquifer dewatering does not really exist with the historic total pumping rates of 3,000 gpm or more. This indicates that, at least in the vicinity of the Newmark wellfield, the model cannot currently reliably predict groundwater capture. It is therefore reasonable to expect that the project flow model under-predicted the optimum extraction rates. Recent pumping test data for Newmark well no. 3 (URS 1994b) and analytical capture zone calculations (Javandel and Tsang 1986) can be used, in this instance, to supplement flow model extraction simulation results.

2.5   EVALUATION OF RECENT PUMPING TEST RESULTS

Pumping Test

A pumping test was conducted at the Newmark wellfield from April 26, 1994 to May 2, 1994. Newmark well no. 3 was used as the pumping well, and Newmark well no. 2, monitoring wells MW02A and B, MW04A and B, and MW05A and B were used as observation wells. The test involved a 48-hour constant-rate pumping test followed by an 8-hour recovery test. Water level drawdown and recovery were analyzed using three methods: Cooper and Jacob semilog (1946), Boulton curve match (1954), and Cooper and Jacob distance drawdown (1946). Aquifer transmissivities and storage coefficients were calculated using these methods. Details of the pumping test were presented in Pump Test Technical Memorandum for Newmark OU (URS 1994b).

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Capture Zone Calculation Method

The procedure presented by Javandel and Tsang (1986) was adapted to estimate capture for the Newmark wellfield extraction system. This method is an analytical approach and assumes a homogeneous, isotropic aquifer with uniform thickness under uniform, steady regional flow conditions. It was assumed that the extraction wells penetrate the full thickness of the aquifer. The single well capture zone can be calculated using the following equation (Javandel and Tsang 1986):

$$y = \pm \frac{Q}{2BU} - \frac{Q}{2\pi BU} \tan^{-1}\left(\frac{y}{x}\right) \tag{1}$$

where   x , y =   cartesian coordinate of capture zone (feet)
                         [location of single well represents origin (or 0,0) of coordinate system]
              Q   =   pumping rate (gallon/day)
              B   =   aquifer thickness (feet)
              U   =   regional groundwater flow velocity (feet/day)

The capture zone width can be calculated using the following equation:

$$Y_{max} = \frac{Q}{BU} \tag{2}$$

where Y_{max} =   maximum width of capture zone far upgradient of the extraction well (feet)

Parameters

Analysis of pumping test data from Newmark well no. 3 (URS 1994b) provided transmissivities ranging from 12,100 ft²/d to 73,300 ft²/d. These transmissivities were calculated using pumping and recovery test data. The recovery test data were considered to more closely reflect the aquifer parameters due to the reduced potential for water level irregularities (because no pumping occurs during recovery). For this reason, the transmissivities calculated using the recovery data were preferred for capture zone calculations. The average transmissivity used for this study was 17,000 ft²/day. Using the relation

$$T = KB \tag{3}$$

where   T   =   transmissivity of the aquifer (square feet/day); and,
              K   =   hydraulic conductivity of the aquifer (feet/day),

the average transmissivity for the pumping test at Newmark well no. 3 can be equated to an average hydraulic conductivity for the aquifer in this area. Given a calculated aquifer thickness (B) of 317 feet (using the difference between depth to static water and the bottom of the aquifer), the calculated hydraulic conductivity was approximately 54 ft/day. The hydraulic gradient (i) was calculated at 0.019 ft/ft (or dimensionless) using recent groundwater level measurements (April to May 1993).

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The regional flow velocity (U) can be calculated using the relation
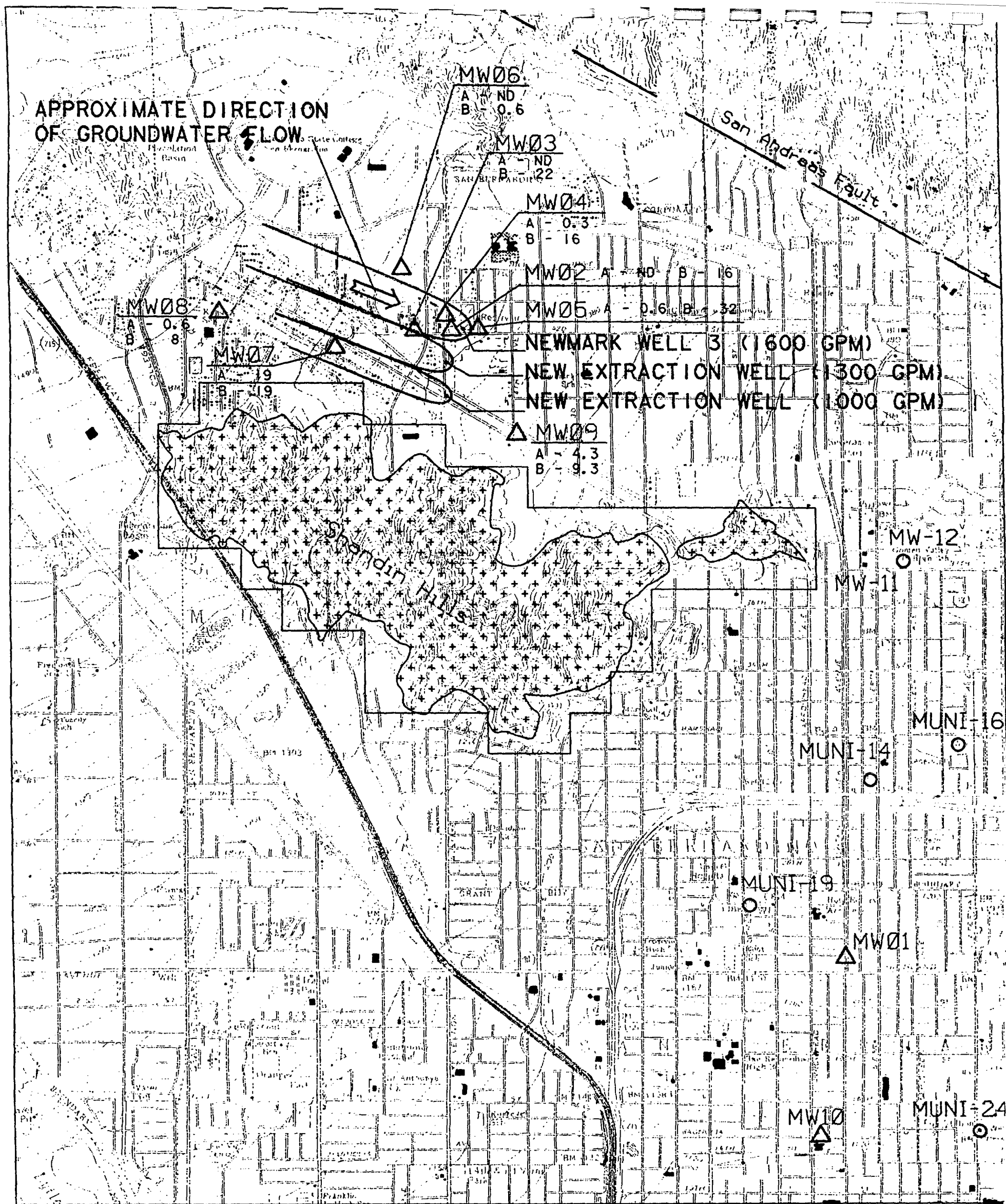
$$U = Ki \tag{4}$$

where   i   =   hydraulic gradient in the extraction region (dimensionless)

Substituting for K and i gives a regional flow velocity of approximately 1.0 ft/day.

2.6 PROPOSED EXTRACTION WELL SYSTEM

Figure 2 shows locations and the individual capture zones (calculated using Equation 1) for the proposed extraction well system. Three extraction wells were considered pumping at the following constant rates: Newmark well no. 3 at 1,600 gpm; one new extraction well @ 1,300 gpm; and a second new extraction well at 1,000 gpm. These flow rates and the aquifer parameters presented in subsection 2.5 were used in Equation (1) to calculate the individual well capture zones shown on Figure 2. The figure shows the overlapping capture zones covering the width of the groundwater contaminant plume. The total pumping rate for the proposed extraction system was 3,900 gpm. The proposed extraction wells will be screened over a portion of the aquifer to optimize contaminant capture (probably the lower portion of the aquifer).

Several pumping scenarios using various pumping rate combinations were considered. Based on the available data, aquifer parameters used during capture zone calculations, and flow model simulations, the extraction scenario presented here is considered optimum. Inclusion of the existing Newmark wellfield in the extraction system allows for maximum flexibility in the event that additional pumpage is needed (e.g., large regional water level fluctuations) at the Newmark wellfield.

APPROXIMATE DIRECTION
OF GROUNDWATER FLOW

San Andreas Fault

MW06
A - ND
B - 0.6

MW03
A - ND
B - 22

MW04
A - 0.3
B - 16

MW02 A - ND B - 16

MW05 A - 0.6 B - 32

NEWMARK WELL 3 (1600 GPM)
NEW EXTRACTION WELL (1300 GPM)
NEW EXTRACTION WELL (1000 GPM)

MW08
A - 0.6
B - 8

MW07
A - 19
B - 19

MW09
A - 4.3
B - 9.3

Shandin Hills

MW-12

MW-11

MUNI-16

MUNI-14

MUNI-19

MW01

MW10

MUNI-24

LEGEND

⬡ Bedrock Outcrop

⌐ Boundary of
No Flow Area

⟋ Capture Zone

1000 GPM Extraction Rate

△ Monitoring Wells

○ Municipal Supply Wells

A - 0.3 PCE Concentration (ug/l) in Subunit A

B - 6 PCE Concentration (ug/l) in Subunit B

Note : Concentrations of PCE in Groundwater are
Based on April 1993 and November 1994
Sampling Data.

Only PCE Data In The Wells Near The
Newmark Wellfield are Shown

ND - Non-Detect

0'   2000'   4000'

SCALE IN FEET

FIGURE 2

PROPOSED EXTRACTION
WELL LOCATIONS
AND CAPTURE ZONES
NEWMARK WELLFIELD AREA

| URS Consultants, Inc.
Sacramento, Ca | NEWMARK OU RD
NEWMARK GROUNDWATER CONTAMINATION SUPERFUND SITE |

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3.0 CONCLUSION

Five extraction scenarios were evaluated for their ability to capture imaginary particles using the project flow model. Based on the uncertain results of the modeling runs and the area-specific limitations of the model, an analytical procedure was used to supplement the flow model simulations. The procedure was adapted from a simple method to calculate capture zones presented by Javandel and Tsang (1986). Using available aquifer parameters and recent pumping test results from Newmark well no. 3 (URS 1994b), capture zones were calculated for one existing municipal supply well (Newmark well no. 3) and two proposed new extractions wells. The proposed extraction system consists of three wells pumping at the following constant rates: Newmark well no. 3 at 1,600 gpm; one new extraction well at 1,300 gpm; and a second new extraction well at 1,000 gpm. The calculated capture zones from these three wells appear to adequately cover the inferred contaminant plume width in the vicinity of the Newmark wellfield. The *proposed extraction well system is shown on Figure 2. The precise locations for the new extraction wells* will depend on land accessibility. The well locations and flow rates must be reevaluated if land accessibility causes location changes.

It should be noted that the proposed extraction well system design is an estimate based on the project flow model and analytical calculations of capture zones, and therefore subject to the same uncertainty and limitations as the models. The following limitations particularly affect the well system design: (a) Model Grid Spacing - project flow model uses a grid spacing of 820 feet in x and y directions. Because of the grid size, a minimum well spacing of 820 feet can be used in the model simulation. If smaller well spacings were used, a lower extraction rate might effectively capture the imaginary particles; (b) Extraction Well Screen Lengths - the model does not allow for separate screening intervals within an aquifer or for partial penetration of an aquifer. Although the contamination was modeled over the entire aquifer, the data previously collected suggest that the contamination is limited to the lower portion. The model assumes extraction wells are fully penetrating over the entire model layer (aquifer). This difference could allow the model to predict a greater pumping rate than necessary. Conversely, the area's specific model limitations described in Subsection 2.4 tend to make the model under-predict extraction rates.

The capture zone calculations were based on several simplifying assumptions that produce uncertainty. For instance, the capture zone equations are sensitive to water table fluctuations and the resulting variable pumping rates. This example is relevant because up to 80 feet of water level change has been observed in this area within the last two years. Changing water levels result in variable aquifer thicknesses (B) and regional flow velocities (U). The changing water levels also cause pressure changes in the well pump system, inducing variable pumping rates (Q) that are directly proportional to the water level changes. The results of these water level changes, it follows, equate to variable capture zone sizes, as predicted by Equation (1).

The results of the capture zone calculations presented in Subsection 2.5 reflect high water level conditions. Calculations were also performed for low water level conditions using historic data supplied by the City of San Bernardino Water Department. It appears that the capture zones calculated for low water conditions would be smaller, possibly as much as 200 feet narrower, than those for high water conditions.

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The main impact from large water level changes is a complex variation of capture zones. The capture zone changes are difficult to predict given the uncertain and unpredictable nature of the water level changes, variable regional flow velocities, and aquifer heterogeneities in this area. Considering these factors, it is possible that a third new extraction well (or more) could be necessary to maintain plume capture after the proposed extraction system has begun operation. It is not considered prudent, however, to propose a larger extraction system at this time. The system should be evaluated after operating and monitoring data become available.

The proposed extraction wells will be screened over a portion of the aquifer to optimize contaminant capture (probably the lower portion of the aquifer). Actual pumping rates will be based on pumping tests performed on the newly constructed wells. Regardless, the proposed design is considered optimum based on currently available data.

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